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Abstract

In this study, we investigate the role of receptivity to novelty in innovation and long-run economic growth. Consumers' receptivity to novelty, as an individual propensity toward new goods, might be perceived to encourage innovation and economic growth at the aggregate level unambiguously. Recent evidence, however, suggests an inverted U-shaped relationship between average receptivity and macroeconomic performance in terms of innovation and growth; receptivity may not always be good for the aggregate economy. To capture a mechanism behind this fact, we develop a new R&D-based growth model with the understanding that innovation consists of two separate activities of inventing new goods and introducing them to the society. In our model, consumer receptivity encourages firms to invent but discourages them from introducing. Interacted with population size and the elasticity of substitution, these opposing forces generate a non-monotonic relationship. While economies with moderate receptivity can achieve sustained innovation and thereby long-run growth, those with too much or too little receptivity are likely to be caught in an underdevelopment trap, in which innovations eventually fail. These results suggest a theory that explains the inverted U.

JEL Classification Codes: E32; O40; Z10

Keywords: Openness to novelty; aversion to novelty; underdevelopment traps; endogenous growth; innovation cycles

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1 Introduction

It is generally believed that people’s receptivity to novelty or new ideas is important for innovation. For example, Mokyr (1991) writes: “[T]he success of new techniques depends both on the level of inventive activity and the receptivity of the surrounding economy to new ideas.” More recently, Fagerberg (2005, 2013) argues that “‘openness’ to new ideas, solutions, etc. is essential for innovation” because innovation requires people and firms to “search widely for new ideas, inputs and sources of inspiration.” Since innovation is widely recognized as a major driver for long-run growth, one may also think that the public’s preferences for novelty are pivotal to economic growth and development.

The inspection of data, however, reveals a non-trivial relationship between the public’s preferences for novelty and economic performance at the country level. Gören (2017) finds a stable inverted U-shaped relationship between novelty-seeking personality traits and economic development.¹ Novelty seeking is a widely-accepted psychological concept that is defined as a human personality trait associated with “exhilaration or excitement in response to novel stimuli” (Cloninger 1986), which naturally captures a crucial aspect of people’s receptivity to novelty. In addition, surprisingly enough, we find that the relationship between the public’s preferences for novelty and *innovation itself* may also be inverted U-shaped. Figure 1 shows the country-level relationship between individual receptivity to novelty and the number of patent applications per million capita.² Recent evidence, thus, suggests a non-monotonic relationship between the public desire for novelty and such major macroeconomic variables.

What accounts for these seemingly counter-intuitive relationships? How do individuals’ preferences towards new ideas affect aggregate innovation and growth? These questions require a new framework where the effects of individuals’ preferences for novelty on innovation and economic growth can be studied. By presenting such a new framework, the present study offers a market-based explanation for the non-monotonic effects of receptivity on the aggregate economy.³ To do this, we focus on “technological inertia” (Mokyr 1992) as a missing link. In the history of technological innovation, as Mokyr argues, most societies have exhibited a strong resistance to innovation, experiencing technological stasis. Therefore, new inventions often fail to be implemented or introduced into the society despite their ostensible economic superiority; the introduction of a new invention is a highly uncertain, difficult, and individual event (Mokyr 2000, 2004).⁴

We develop a new research and development (R&D)-based growth model *à la* Romer (1990), in which ideas are first invented as new goods and, eventually, become either

¹Novelty-seeking traits are measured by the country-level genome data on DRD4 exon III allele frequencies, which are “sometimes associated with the human personality trait of novelty-seeking behavior” (Gören 2017). As usual, economic development is measured by GDP per capita.

²We measure receptivity to novelty, based on the survey data, by whether the people in the country consider that new ideas are better than old ones. The number of patent applications is a standard measure of innovation. In Appendix A, we will provide a more formal regression analysis that confirms the inverted-U relationship, together with further details about the data sources and variable definitions.

³This will complement Gören (2017), who, in his simple model, hypothesizes (rather than explains) the potential benefits and costs of novelty seeking traits for the level of public knowledge, with a reasonable justification that is rigorously based on empirical evidence.

⁴A good example for this tendency is Crete’s Phaistos Disk in about 1700 B.C. (Diamond 1997), which indicates the early invention of an efficient printing technique, but it received little social acceptance. Being lost for a long time, printing technology was reinvented and widely introduced in Renaissance Europe and, then, spread worldwide. Even for inventions that will eventually take root in society, the path from invention to introduction is far from smooth; see Diamond (1997) for more examples.

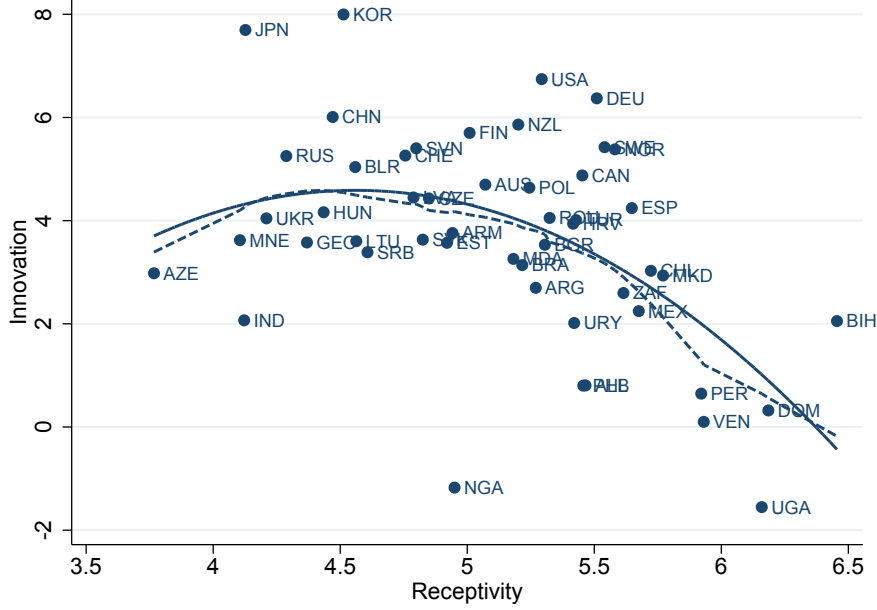


Figure 1: Receptivity and innovation: Cross-country relationship

Note: Innovation is measured by patent applications per million capita (log) and receptivity is measured by World Values Survey's question E046. The solid line is a fitted quadratic curve. The dotted line is a Lowess smoothing curve.

matured to survive as long-lasting (or “old”) goods or obsolete. Whether a new invention is ultimately introduced into the economy is uncertain, in accordance with the nature of technological progress as mentioned above. A critical assumption is that the invention (of new ideas as new goods) and the introduction (of new goods into old goods) are separate innovative activities that both require investments. Their profitabilities are, thus, governed by the consumers’ desire for newly-invented goods (or their “receptivity to novelty”).

Using the model, we will offer an economic, market-based explanation for the non-monotonic relationship between receptivity to novelty and macroeconomic performance. In doing this, first, we identify two interactive factors generating the ambiguous effect of receptivity on innovation: (a) the market mechanism, which encourages the development of goods that earn a relatively large profit, and (b) a matching efficiency effect, which enriches the “innovation-possibilities frontier” by agglomerating new inventions, which are not innovation itself but the origin of “innovation” in the present context. These two forces are complementary in the sense that, while the latter reduces the cost for innovation, the former determines the distribution of resources to investments in inventing new goods and saving them from obsolescence in each period of time. We will demonstrate that the receptivity to novelty, together with the elasticity of substitution between goods, plays an essential role in determining the balance between these two factors. As a result of this, we will also show that consumer receptivity encourages firms to invent but discourages them from introducing, which generate a non-monotonic relationship between receptivity and innovation.

The core finding of this study is that only those economies with moderate receptivity

to novelty can achieve self-sustained innovation and growth in the long run; when consumers' receptivity to novelty is too high or too low, their economy tends to be caught in an "underdevelopment trap," in which case new goods are invented over time but all become obsolete along an equilibrium path, i.e., there is no innovation in the long run.⁵ The intuition behind our core finding is as follows: On the one hand, when consumers are too averse to novelty, the demand for and profits related to newly-invented goods will be relatively small so that almost no new goods are invented in the marketplace (through the market mechanism). Since it shrinks the innovation-possibilities frontier, the cost incurred by firms in introducing new goods into the society becomes higher (due to the matching efficiency effect). In equilibrium, only invention occurs, but less actively; there is no innovation in the long run.⁶ On the other hand, when consumers are too open to novelty, the demand for and profits related to newly-invented goods are large, relative to old goods. In such a scenario, invention is even more profitable than introduction and there are more new goods to be invented in the marketplace (through the market mechanism). Although abundant inventions imply a lower cost for innovation (due to the matching efficiency effect), the economy is specialized in inventing new ideas on an equilibrium path when consumers are highly open to novelty, yielding, once again, a lack of innovation. Therefore, with too-low or too-high receptivity, the economy is caught in an underdevelopment trap and has no innovation. In a trapped economy, there is no economic growth in the long run.

We formally prove that only those economies with moderate receptivity to novelty can achieve self-sustained innovation and growth in the long run. In this case, both forces, as explained above, interact with each other, whereby the economy perpetually fluctuates between periods where new goods are invented and periods where invented goods are introduced escaping from obsolescence. Over the cycle, innovation persists, but intermittently.⁷ In this case, the economy perpetually grows on an equilibrium path. Therefore, we conclude that innovation and growth may be depressed by too-high or too-low receptivity to novelty on the part of the representative consumer, suggesting a theory that provides a useful basis for interpreting the observed inverted-U as mentioned above.

Our theoretical finding also offers a market-based explanation on the observation that, throughout history, invention and introduction have taken place cyclically (e.g., Mokyr 2000),⁸ by showing the existence of an innovation cycle over which invention and introduction alternate along an equilibrium path. Therefore, we contribute to a large theoretical literature that investigates the possibility of perpetually cyclical innovation as an endogenous phenomenon (Shleifer 1986, Deneckere and Judd 1992, Gale 1996, Francois and Shi 1999, Matsuyama 1999, 2001, Yano and Furukawa 2013, Furukawa 2015), to which our innovation cycle (between periods of invention and introduction) is new. As is well known in this literature, an essential factor for innovation cycles is the temporary nature of monopoly power. We follow the literature when we assume the one-period monopoly in a discrete time model.

⁵Here, the trap can be regarded as a kind of low-level equilibrium trap (Nelson 1956) because, in the present model, no innovation results in zero long-run growth in national income.

⁶Note that we assume that new goods rapidly become obsolete without introduction, while introduced goods take root in the economy to contribute to long-run growth.

⁷In the baseline model, as explained here, an innovative economy is always perpetually cyclical. In Section 5, however, we will show that it can also stably converge to a unique balanced growth path, by considering a natural extension of the baseline model.

⁸See also footnote 4.

In addition to receptivity to novelty, we focus on two other important factors that interact with receptivity to affect innovation and growth. The first is gross substitutability between goods. The mechanism through which the consumer's receptivity affects innovation is at work only when receptivity changes the expenditure share for newly invented goods; it does not work if the elasticity of substitution between goods is equal to 1 (i.e., a Cobb–Douglas case). The second factor is country size. When a country has a large population, the demand and profit for any firm are larger; this promotes all stages in the innovation spectrum by making both invention and introduction activities more profitable. Thus, larger-sized economies are more likely to achieve perpetual innovation.⁹

Our paper is closely related to a growing body of literature on culture and growth. The seminal paper by Galor and Moav (2002) shows that individual preferences for offspring quality play a role in population growth and human capital formation.¹⁰ Among subsequent studies, from a theoretical viewpoint, the most closely related ones are Galor and Michalopoulos (2012) and Deopke and Zilibotti (2014). Both analyses identify the critical role of entrepreneurial traits in innovation and economic growth by considering an endogenous evolution of the fraction of people who exhibit an entrepreneurial spirit (in terms of risk tolerance).¹¹ They highlight a positive interplay between novelty-seeking personal traits and economic growth at the country level. The present paper contributes to this theoretical literature in the following two respects: (a) we focus on the consumer's preference for newly invented goods relative to old goods (receptivity) as another important aspect of people's novelty-seeking traits, and (b) we identify the potential benefits and costs of receptivity for innovation and growth at the aggregate level.

From an empirical viewpoint, various studies have investigated the relationship between cultural factors and economic development. For example, Tabellini (2010) shows that cultural propensities such as trust have a significant effect on regional per-capita income in Europe. Alesina and Giuliano (2010) examine the effects of family ties on economic performance.¹² As we already mentioned, Gören (2017) is closely related; he uses molecular genetic data to find an inverted U-shaped relationship between some kind of receptivity to novelty and economic development. The present paper complements those papers by (a) providing new evidence suggesting that the country-level relationship between individual receptivity and *innovation* is also inverted U-shaped and (b) offering a new full-fledged R&D-based growth model that is equipped to explain the inverted-U effects of receptivity on innovation and growth.

Our paper is also related to the literature on two-stage innovation models, which distinguishes basic and applied research (see, e.g., Aghion and Howitt 1996, Michelacci 2003, Akiyama 2009, Cozzi and Galli 2009, 2013, 2014, Acs and Sanders 2012, Chu et al. 2012, Chu and Furukawa 2013, Konishi 2015). Noting that the two separate activities

⁹As discussed later (after Lemma 4), this is in line with Boserup's (1965) view. See Kremer (1993) for a more recent study.

¹⁰Subsequent studies by Ashraf and Galor (2007, 2013a, 2013b, 2017) explore cultural/genetic diversity and regional development at different stages and in different places.

¹¹See also Chu (2007), who provides the interesting argument that entrepreneurial overconfidence can cause different rates of economic growth across countries. Moreover, Chu and Cozzi (2011) focuses on cultural preferences for fertility. In a broader context, as Yano (2009) points out, the coordination of such cultural factors with laws and rules is indispensable to deriving high quality markets and thereby healthy economic growth. The present study extends this literature by investigating a composition effect of receptivity to novelty, patent protection, and population on long-run economic growth.

¹²See also Benabou et al. (2015, 2016), who show that innovation can be negatively associated with people's religiosity.

of innovation in our model both earn profits, our study complements this literature by exploring two different processes of applied research, i.e., the invention of a new product and its introduction.

The remainder of this paper is organized as follows. Section 2 presents a new R&D-based growth model that incorporates invention and introduction as separate innovative activities and derives equilibrium conditions. Section 3 characterizes the equilibrium dynamics of the model. Section 4 identifies the critical role of receptivity in innovation and growth in the long run. Section 5 provides an extension of the baseline model, showing that our economy can also experience dynamic phenomena such as balanced growth and history dependence, in addition to underdevelopment traps and innovation. Finally, Section 6 provides concluding remarks.

2 An R&D-based Growth Model of Invention and Introduction

Time is discrete and extends from 0 to ∞ . We think of an R&D-based growth model with expanding varieties *à la* Romer (1990). We extend the standard variety-expansion model (a) by considering that innovation consists of two separate activities of inventing new goods and introducing them to the economy (based on the historical argument of Mokyr (2004)), (b) by parameterizing consumer receptivity to newly invented goods (in order to explore the role of individual receptivity in aggregate innovation), and (c) by considering the temporary nature of monopoly (that follows the innovation cycle literature (Shleifer 1986)). In summary, consumer receptivity encourages firms to invent new goods in equilibrium but discourages them from introduce. These two opposite effects of receptivity can generate a non-monotonic relationship between receptivity and innovation in the long-run equilibrium and also cause perpetual cycles on an equilibrium transitional path.

2.1 Consumption and Receptivity

In the economy, there is an infinitely lived representative consumer, who inelastically supplies L units of labor in each period. The infinitely lived consumer solves the standard dynamic optimization of consumption and saving:

$$\max U = \sum_{t=0}^{\infty} \beta^t \ln u(t), \quad (1)$$

where $\beta \in (0, 1)$ is the time preference rate and $u(t)$ is an index of consumption in period t . Since our focus is on consumers' receptivity, we follow Grossman and Helpman (1991) by assuming that periodic utility u is defined over differentiated *consumption goods*, with each indexed by j .¹³ As is standard in the literature, we consider a constant elasticity of

¹³In this class of the R&D-based growth model, the variety of consumption goods endogenously increases over time, unlike in the original Romer model (in which the variety of intermediate goods increases). Therefore, in the present model, patents are granted for consumption goods, but they are often for intermediate goods in reality. Nevertheless, we adopt the present setting because we are interested in consumers' receptivity to novelty. Note, however, that we can obtain similar results even if we consider an expanding variety of *intermediate* goods.

substitution utility function as:

$$u(t) = \left(\int_{j \in A(t) \cup N(t)} (\varepsilon(j, t) x(j, t))^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \quad (2)$$

where $x(j, t)$ denotes the consumption of good j in period t and $\sigma \geq 1$ is the elasticity of substitution between any two consumption goods. The consumption goods are categorized into two types: new goods and old goods. Let $N(t)$ be the set of new goods invented in period t and $A(t)$ be the set of old goods. An old good is a fundamental good that is fully introduced and takes root in the economy, so that it does not become obsolete. For simplicity of the description, let $A(t)$ or $N(t)$ also denote the number (measure) of goods.

A new good is a newly invented design of a good, which is “fragile” in the following sense. Unlike an old good, a new good may be only transient and, thus, become obsolete after being consumed for one period. Consumers differentiate new and old goods because they are endowed with not only a love of variety, but also a love of novelty, so to speak. We incorporate such references to novelty into the model, by means of a weight function, $\varepsilon(j, t)$, which is specified as

$$\varepsilon(j, t) = \begin{cases} 1 & \text{if } j \in A(t) \text{ (old goods)} \\ \varepsilon & \text{if } j \in N(t) \text{ (new goods)} \end{cases}. \quad (3)$$

In (3), the old goods are weighted with $\varepsilon(j, t) = 1$ (normalization), while the new goods are weighted with $\varepsilon(j, t) = \varepsilon \geq 0$.¹⁴ We interpret the weight of new goods ε as a measure of how open consumers are to newly invented products. We refer to ε as the consumer’s *receptivity to novelty*. If consumers have no receptivity to novelty whatsoever (or, a complete aversion to novelty), it holds that $\varepsilon = 0$, in which case they do not exhibit any preference with regard to new goods. Consumers with receptivity to novelty (i.e., with $\varepsilon > 0$) will feel some utility for new goods. In line with Gören (2017), we may also refer to this preference parameter ε as capturing a consumer’s degree of “novelty seeking.” As we already explained, novelty seeking is a widely-accepted psychological concept that is defined as a human personality trait associated with “exhilaration or excitement in response to novel stimuli” (Cloninger 1986). Since consumers in different cultures can have different degrees of novelty seeking on average (Chandrasekaran and Tellis 2008, Tellis et al. 2009), we may consider ε as an intrinsic parameter on the preference that historically and culturally characterizes a society.¹⁵

Each good j , a new or old good, is dominated by a monopolistic producer. We consider a one-for-one technology in goods production. Namely, any producer, $j \in A(t)$ or $N(t)$, hires $x(j, t)$ units of labor to produce $x(j, t)$ units of good j , and monopolistically sells them to the consumer.

2.2 Innovation through Invention and Introduction

We extend the endogenous process of innovation *à la* Romer (1990) by considering that a newly invented good will become obsolete or survive to be introduced into the society

¹⁴One may think it is more natural to assume $\varepsilon < 1$. In some cases, however, people can show an unusually strong affinity for new goods (relative to old goods), so we allow for ε to be higher than 1 although it does not change our results essentially.

¹⁵The view that the degree of novelty seeking, or receptivity to novelty, varies has also been considered in consumer research (Hirschman 1980) and business (Rogers 1962, Rogers and Shoemaker 1971).

as an old good; in this process, both invention and introduction are endogenous activities that require time and resources.

A potentially infinite number of firms can be involved in the innovation process. Any firm can invent a new good in period $t + 1$ by making an investment of $1/A(t)$ units of labor in period t . Following Romer (1990), we consider “external effects arising from knowledge spillovers” of cumulative technologies, represented by $A(t)$.¹⁶

An old good is, in contrast, an introduced good that takes root in the society and is never obsolete, from which an economy will permanently have utility. In our view, transforming a new good into such a well-established good is concerned with compelling consumers to be knowledgeable of and fully accept it. Investment in introduction, thus, covers various activities, including marketing, advertising, and lobbying, as well as some technical improvements.

Analogous to invention firms, a potentially infinite number of firms can be engaged in introduction activities. A firm, first, invests one unit of labor to search through the set of new goods, $N(t)$, in period t ; then, it can find $\chi(t)$ units of new goods from $N(t)$, and introduce these new goods into the society in period $t + 1$, thus, earning monopolistic profits. In this process, new goods are transformed into old goods. We consider a linear technology, $\chi(t) \equiv \kappa N(t)$, in which $\kappa > 0$ is a productivity parameter.¹⁷ With this function, we naturally assume that firms can find more new goods when there are more new goods in the economy. When introduction happens, we say that the economy brings about innovation, by which we mean the entire process in which new goods are invented and, then, introduced to take root in society (as old goods).

The law of motion governing the growth of old goods, $A(t)$, is given by

$$A(t + 1) - A(t) = \chi(t)R^A(t) \leq N(t), \quad (4)$$

in which $R^A(t)$ denotes the number of firms that invest in introduction activities in period t . None of old goods becomes obsolete since they fully take root in the economy.¹⁸ Meanwhile, we assume that the new goods that are not introduced become obsolete. We, thus, express the evolution of $N(t)$ as:

$$N(t + 1) = R^N(t), \quad (5)$$

where $R^N(t)$ denotes the number of firms that invest in invention activities in period t . Here, a macroeconomic rate at which new goods are accepted as old goods in society from period t to $t + 1$ is equal to

$$\chi(t)R^A(t)/N(t) \equiv \rho(t + 1). \quad (6)$$

Unlike consumer receptivity ε as a preference parameter, one may interpret $\rho(t + 1)$ as an equilibrium rate of receptivity at the aggregate level.

¹⁶We suppose that there is no spillover from newly invented goods, since they are so new that their information would not be diffused well. Nevertheless, even if we allow for new goods $N(t)$ in public knowledge, the main results will not qualitatively change.

¹⁷From a broader perspective, this κ can relate to firms’ absorptive capacity (Cohen and Levinthal 1989).

¹⁸We could allow for some small depreciation for $A(t)$, without rendering any essential change to the result.

2.3 Market Equilibrium

The infinitely lived consumer solves static optimization in (1); as is well known, we have the demand functions:

$$x(j, t) = \varepsilon(j, t)^{\sigma-1} \frac{E(t)p(j, t)^{-\sigma}}{P(t)^{1-\sigma}}, \quad (7)$$

where $E(t) \equiv \int_{j \in A(t) \cup N(t)} p(j, t)x(j, t)dj$ is the spending on differentiated goods, $p(j, t)$ denotes the price of good j in period t , and $P(t)$ is the usual price index, defined as:

$$P(t) \equiv \left(\int_{j \in A(t) \cup N(t)} (p(j, t)/\varepsilon(j, t))^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}. \quad (8)$$

Solving dynamic optimization, we also obtain the Euler equation:

$$\frac{E(t+1)}{E(t)} = \beta(1 + r(t)), \quad (9)$$

where $r(t)$ stands for the interest rate.

We assume that producing one unit of goods requires one unit of labor and, thus, the marginal cost is equal to the wage rate, $w(t)$. By (7), the consumption good producers, $j \in A(t) \cup N(t)$, face a constant price elasticity of market demand, equal to $\sigma \geq 1$. The unconstrained mark-up for a monopolistic producer is $\sigma/(\sigma - 1) > 1$. To allow for a Cobb-Douglas case with $\sigma = 1$, we follow Li (2001), Goh and Olivier (2002), and Iwaisako and Futagami (2013) and introduce an upper bound of the mark-up—say, $\mu > 1$ —by considering potential imitators whose production cost increases with so-called patent breadth.¹⁹ The breadth of a patent is identified with “the flow rate of profit available to the patentee” and often interpreted as “the ability of the patentee to raise price” (Gilbert and Shapiro 1990). Following the literature, we regard μ as the breadth of a patent and assume $\mu < \sigma/(\sigma - 1)$.²⁰ Each firm, thus, sets a monopolistic price at:

$$p(j, t) = \mu w(t) \quad (10)$$

for all j . Using (3), (7), and (10), the output and monopolistic profit for a new good are given by:

$$x(j, t) = \frac{\varepsilon^{\sigma-1} E(t)}{P(t)^{1-\sigma}} (\mu w(t))^{-\sigma} \equiv x^n(t) \text{ for } j \in N(t) \quad (11)$$

and

$$\pi(j, t) = \varepsilon^{\sigma-1} \frac{\mu - 1}{\mu^\sigma} E(t) \left(\frac{w(t)}{P(t)} \right)^{1-\sigma} \equiv \pi^n(t) \text{ for } j \in N(t). \quad (12)$$

Equation (12) shows that when $\sigma > 1$, the profit for a new good, $\pi^n(t)$, increases with consumer receptivity, ε , and the total expenditure, $E(t)$, and decreases with the real wage, $w(t)/P(t)$.²¹

We follow Shleifer (1986), Deneckere and Judd (1992), Gale (1996), Francois and Shi (1999), Matsuyama (1999, 2001), and Furukawa (2015) by assuming that the monopolistic firm earns a profit only for one period. The one-period monopoly has also been used in a different context (e.g., in the field of directed technical change and the environment) (see

¹⁹See, for example, Chu et al. (2016) for a more recent examination.

²⁰The upper bound of a mark-up, μ , can also be seen as a result of price regulation (Evans et al. 2003).

²¹We will also see the case of $\sigma = 1$.

Acemoglu et al. 2012). Therefore, the firm inventing good j enjoys only a one-period monopoly. The discounted present value of creating a new good can be written as:

$$W^n(t) \equiv \frac{\pi^n(t+1)}{1+r(t)} - \frac{w(t)}{A(t)}. \quad (13)$$

We also follow Acemoglu et al. (2012) by assuming that, after one period, monopoly rights will, then, be allocated randomly to a firm drawn from the pool of potential monopolistic firms. Consequently, in our model, goods are all monopolistically competitively produced in equilibrium. Alternatively, we could also proceed in such a way that goods with expired patents are sold at a perfectly competitive price (e.g., Matsuyama 1999) or become obsolete (e.g., Furukawa 2015). However, we understand that either option will complicate the analysis without garnering any new insights. Although it could be an interesting extension, we keep the analysis as simple as possible to highlight the main issue discussed in the Introduction.

Analogous to the case of a new good, $j \in N(t)$, by (3), (7), and (10), the output and monopolistic profit for an old good are given by:

$$x(j, t) = \frac{E(t)}{P(t)^{1-\sigma}} (\mu w(t))^{-\sigma} \equiv x^a(t) \text{ for } j \in A(t) \quad (14)$$

and

$$\pi(j, t) = \frac{\mu - 1}{\mu^\sigma} E(t) \left(\frac{w(t)}{P(t)} \right)^{1-\sigma} \equiv \pi^a(t) \text{ for } j \in A(t), \quad (15)$$

respectively. The profit associated with an old good increases with the expenditure, $E(t)$, and decreases with the real wage, $w(t)/P(t)$. Given the one-period patent protection, the discounted present value of introducing an old good is expressed as

$$W^a(t) \equiv (\kappa N(t)) \frac{\pi^a(t+1)}{1+r(t)} - w(t). \quad (16)$$

As shown in (12) and (15), the real wage $w(t)/P(t)$ is an important component of the profits. It is, thus, beneficial to have

$$\frac{w(t)}{P(t)} = \frac{1}{\mu} [A(t) + \varepsilon^{\sigma-1} N(t)]^{\frac{1}{\sigma-1}}, \quad (17)$$

which uses $p(j, t) = \mu w(t)$ for any $j \in A(t) \cup N(t)$ with (8).

Under the free entry of firms into innovation, the present value of their payoff must be equal to or less than 0:

$$W^n(t) \leq 0 \text{ and } W^a(t) \leq 0, \quad (18)$$

for any $t \geq 0$. The labor market clearing condition is:

$$L = \underbrace{\int_{j \in A(t) \cup N(t)} x(j, t) dj}_{\text{production}} + \underbrace{R^A(t)}_{\text{introduction}} + \underbrace{\frac{R^N(t)}{A(t)}}_{\text{invention}}, \quad (19)$$

where $\chi(t)R^A(t)/N(t) \equiv \rho(t+1)$. Using (11), (14), (17), and (19),²² the labor demand from the production sector is calculated as

$$\int_{j \in A(t) \cup N(t)} x(j, t) dj = \frac{1}{\mu} \frac{E(t)}{w(t)}. \quad (20)$$

3 Equilibrium Dynamics

We are now ready to derive the dynamical system that characterizes the law of motion that determines the equilibrium trajectory of the economy. In doing this, it is beneficial to define $n(t) \equiv N(t)/A(t)$, which is the ratio of new to old goods. The equilibrium dynamics can be completely characterized by means of this knowledge ratio. By the free entry conditions in (18), along with (12), (13), (15), and (16), we derive the following lemma.

Lemma 1 *Only the invention of a new good takes place in equilibrium when $n(t) < \varepsilon^{\sigma-1}/\kappa$. Only the introduction of a new good takes place when $n(t) > \varepsilon^{\sigma-1}/\kappa$.*

The cut-off level of $n(t)$, $\varepsilon^{\sigma-1}/\kappa$, generates two equilibrium regimes in the economy. The first corresponds to $n(t) \in (0, \varepsilon^{\sigma-1}/\kappa)$, which we call an invention regime; there, only invention takes place. The second corresponds to $n(t) \in (\varepsilon^{\sigma-1}/\kappa, \infty)$, which we call an introduction regime; there, only introduction takes place. At the cut-off point, the economy includes both activities; however, we can ignore it, since the point has zero measure.

As shown in Lemma 1, a kind of specialization takes place in the present model. In reality, any economy appears to be engaged in both invention and introduction, more or less, at any point in time. Therefore, this model captures only a certain aspect of real-world behavior—that is, the economy invests in either invention or introduction. We can easily remove this unrealistic aspect concerning specialization from the model by assuming, for instance, a strictly concave function in invention and introduction. As this would provide a deeper analysis but make the analysis intractable, we adopt the present setting for simplicity, given that it is among the first to address the relationship between receptivity to novelty and innovation.

As discussed in the Introduction, there are two interactive forces determining the role of consumer receptivity to novelty ε in innovation, that is, the market mechanism and the matching effect. Lemma 1 reveals the first force. To elaborate this, we will temporarily restrict ourselves to short-run equilibrium, by focusing on one particular period, say t . Note that in each period, t , the value of $n(t)$ is supposed to be given, since it is a pre-determined (stock) variable (that actually changes over time). In the hypothetical situation in which $n(t)$ is taken as given, Lemma 1 implies that, for a given $n(t)$, an economy is engaged in invention activity in equilibrium if (and only if) the invention regime, $(0, \varepsilon^{\sigma-1}/\kappa)$, is sufficiently large (relative to $n(t)$). Since the consumer's desire for new goods, relative to old goods, becomes stronger as ε increases, and since the cost for introduction becomes higher as κ decreases, there is a higher relative profit for

²²Noting (11) and (14), with (17), we have

$$\int_{j \in A(t) \cup N(t)} x(j, t) dj = N(t)x^n(t) + A(t)x^a(t) = \frac{1}{\mu} \frac{E(t)}{w(t)}.$$

the invention of a new good when the individual receptivity to novelty ε is high and/or the productivity for introduction κ is low. Consequently, the economy is more likely to specialize in invention activity for new goods, because the development of technologies that earn a higher profit is encouraged in market equilibrium. For the same reason, an economy is engaged in introduction activity in the short-run equilibrium when $\varepsilon^{\sigma-1}/\kappa$ is small, relative to $n(t)$, in which case there is a higher relative profit for the introduction of a new good. In sum, through the market mechanism, the economy develops new technologies to produce the goods that the consumer relatively prefers, whereby the receptivity to novelty ε plays a role in strengthening invention, rather than introduction.

3.1 Invention Regime

With $n(t) < \varepsilon^{\sigma-1}/\kappa$, by Lemma 1, the economy falls into the invention regime. With (9), (13), (12), and (17), the free entry condition for invention, $W^n(t) = 0$, becomes:

$$N(t+1) = \frac{A(t)}{\varepsilon^{\sigma-1}} \left[\frac{\beta \varepsilon^{\sigma-1}}{\mu/(\mu-1)} \frac{E(t)}{w(t)} - 1 \right], \quad (21)$$

which uses $A(t+1) = A(t)$ (or $\rho(t+1) = 0$). Given $A(t)$, this describes a profit-motive aspect of the inventive activity; the larger the discounted profit from selling new goods ($(\beta \varepsilon^{\sigma-1}(\mu-1)/\mu)E(t)/w(t)$), the greater the incentives for firms to invent a new good. The profit for a new good increases as the wage-adjusted expenditure $E(t)/w(t)$ increases and, at the same time, as the consumer's receptivity to novelty ε increases. With a larger stock of public knowledge, the cost of inventing a new good decreases and firms have greater incentives for invention. Meanwhile, when $n(t) < \varepsilon^{\sigma-1}/\kappa$, no firm has any incentive to invest in introducing a new good; in such a case, $R^A(t) = 0$. The labor market condition (19), thus, becomes:

$$N(t+1) = A(t) \left[L - \frac{1}{\mu} \frac{E(t)}{w(t)} \right], \quad (22)$$

which uses (5) and (20). Given $A(t)$, the greater the wage-adjusted expenditure $E(t)/w(t)$, the more resources will be devoted to production, leaving less for invention; this will result in a smaller $N(t+1)$.

Figure 2 depicts (21) and (22), labeled with FE and LE , respectively, which determine the equilibrium number of new goods, $N(t+1)$, and the wage-adjusted expenditure, $E(t)/w(t)$, as a unique intersection. Looking at this figure, we can see that some standard properties hold in the present model. Given the predetermined variable, $A(t)$, the equilibrium number of new goods $N(t+1)$ is increasing in the time preference rate β , the labor force L , and the patent breadth μ . Given these parameters, the invented goods, $N(t+1)$, is increasing in public knowledge stock $A(t)$.

The effect of the elasticity of substitution between goods, σ , is more interesting. As is standard, σ determines the expenditure share spent on each good. If new goods are preferable to old goods ($\varepsilon > 1$), a higher elasticity of substitution would lead to a higher expenditure share for the new good, resulting in an upward shift of the FE curve in Figure 2. If old goods are preferable ($\varepsilon < 1$), there would be a lower expenditure share for the new good, resulting in a downward shift of the FE curve. When $\sigma = 1$ (i.e., the case of a Cobb–Douglas preference), any expenditure share is always constant and free from receptivity to novelty ε . As a result, the new good $N(t+1)$ is increasing (decreasing)

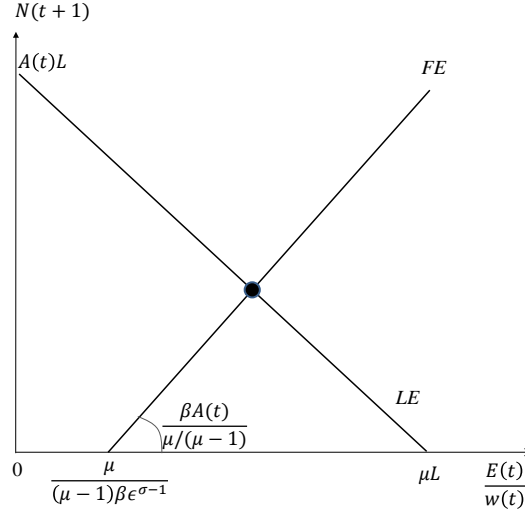


Figure 2: Temporary Equilibrium in the Invention Regime

in the elasticity of substitution σ in an economy with a strong (weak) preference for the new good $\varepsilon > 1$ ($\varepsilon < 1$).

As for the receptivity to novelty ε , a higher ε causes an upward shift in the FE curve. This is simply because the equilibrium profit for new goods, $(\beta\varepsilon^{\sigma-1}(\mu-1)/\mu)E(t)/w(t)$, is higher.²³ The upward shift of the FE curve leads to an increase in $N(t+1)$ in equilibrium. We can formally confirm this effect of ε by solving (21) and (22):

$$N(t+1) = \Theta A(t), \quad (23)$$

where

$$\Theta \equiv \frac{\varepsilon^{\sigma-1}(\mu-1)L - 1/\beta}{\varepsilon^{\sigma-1}((\mu-1) + 1/\beta)}. \quad (24)$$

Equation (23) determines the equilibrium amount of new goods in the invention regime. The coefficient Θ is increasing in the receptivity to novelty ε as well as the standard parameters β , L , and μ . We can interpret the parameter composite Θ as the potential demand for new goods. We assume $\Theta > 0$ to allow for positive growth, by imposing $\varepsilon^{\sigma-1}\beta(\mu-1)L > 1$, which provides a lower bound of ε as $[1/(\beta(\mu-1)L)]^{1/(\sigma-1)} \equiv \varepsilon_0$. Meanwhile, since $R^A(t) = 0$ and thus $\rho(t+1) = 0$ in the invention regime, from (4), the old goods do not grow; $A(t+1) = A(t)$. Therefore, if $\Theta > \varepsilon^{\sigma-1}/\kappa$, it holds that $n(t+1) > \varepsilon^{\sigma-1}/\kappa$, whereby the economy moves to the introduction regime in period $t+1$. Conversely, if $\Theta < \varepsilon^{\sigma-1}/\kappa$, the economy is trapped to stay in the invention regime. We may refer to this situation as an invention *trap*, since there is neither innovation nor growth in the long run (as will be apparent later). While this economy invents new goods every period, both $N(t)$ and $A(t)$ are ever constant in the invention trap. The following lemma summarizes this feature:

²³See also (12).

Lemma 2 *The economy is permanently trapped in the invention regime if and only if $\Theta < \varepsilon^{\sigma-1}/\kappa$.*

Inspection of (23) and (24) reveals the second force determining the role of consumer receptivity ε , that is, the matching effect. From (23), the equilibrium amount of new goods is larger as the invention potential Θ is larger and the old goods $A(t)$ are larger. Given that stronger preferences for new goods increase their potential demand (i.e., Θ increases with ε), the consumer receptivity to novelty ε is conducive to inventions. That is, higher ε yields more new goods to be invented in the marketplace, which essentially increases the efficiency of matching for firms. Firms can find more new goods that they will introduce in the subsequent period. As a result, it encourages aggregate-level innovation in our model.

3.2 Introduction Regime

With $n(t) > \varepsilon^{\sigma-1}/\kappa$, by Lemma 1, the economy is in the introduction regime in period t ; $R^A(t) \geq 0$ and $R^N(t) = 0$. Rearranging the labor market condition (19), with (20), yields the economy's equilibrium rate of receptivity as:

$$\rho(t+1) = \kappa R^A(t) = \kappa \left(L - \frac{1}{\mu} \frac{E(t)}{w(t)} \right). \quad (25)$$

Analogous to (22), (25) captures the trade-off on resources between the production of goods and the investment in introduction. With (9), (15), and (16), the free entry condition for introduction, $W^a(t) = 0$, becomes:

$$\rho(t+1) = \frac{\kappa\beta}{\mu/(\mu-1)} \frac{E(t)}{w(t)} - \frac{A(t)}{N(t)} \quad (26)$$

which uses $N(t+1) = R^N(t) = 0$ from (5), with $\chi(t)R^A(t) = \rho(t+1)N(t)$, and $A(t+1) = A(t) + \chi(t)R^A(t) = A(t) + \chi(t)\rho(t+1)/\kappa$ from (4). Naturally, the equilibrium rate $\rho(t+1)$ of receptivity at the aggregate level increases with the discounted profit from producing the old good $(\beta(\mu-1)/\mu)E(t)/w(t)$. In addition, $\rho(t+1)$ decreases with the number of old goods $A(t)$, since the profit is lower when the economy has sufficient old goods (due to diminishing marginal utility in (2)). It increases with the number of new goods $N(t)$, since firms can find more inventions. Figure 3 illustrates how the equilibrium rate of receptivity $\rho(t+1)$ is determined by (25) and (26). Solving (25) and (26), we obtain:²⁴

$$\rho(t+1) = \frac{1}{1 + \beta(\mu-1)} \left(\kappa\beta(\mu-1)L - \frac{A(t)}{N(t)} \right). \quad (27)$$

The equilibrium rate of receptivity, $\rho(t+1)$, is positively (negatively) correlated with new good $N(t)$ (the old good $A(t)$), through the free entry condition (26). Using (4) and (27), the growth of old goods follows

$$A(t+1) = A(t) \frac{\beta(\mu-1)}{1 + \beta(\mu-1)} \left(1 + \kappa L \frac{N(t)}{A(t)} \right) \quad (28)$$

²⁴Note that $\rho(t+1) > 0$ always holds, with the positive growth assumption, $\varepsilon^{\sigma-1}\beta(\mu-1)L > 1$. In order to retain feasibility, we have to ensure that $\rho(t+1) < 1$, or equivalently $\chi(t)R^A(t) \leq N(t)$, holds entirely in the introduction regime. We do this by imposing $\kappa L < 1 + 1/(\beta(\mu-1))$.

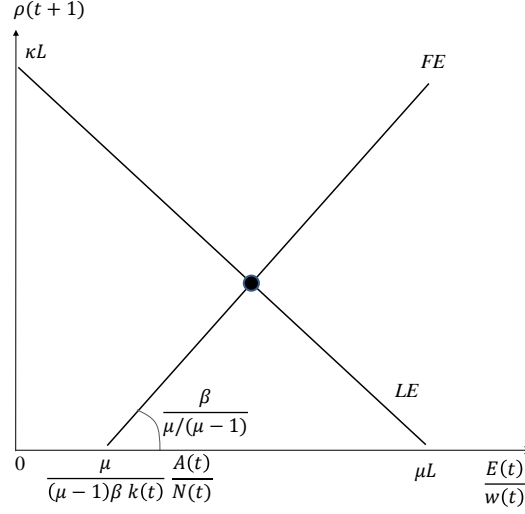


Figure 3: Temporary Equilibrium in the Introduction Regime

In the present regime, the new goods do not grow; $N(t+1) = 0$ from (5). This implies $n(t+1) = 0$, which is clearly lower than $\varepsilon^{\sigma-1}/\kappa$. We therefore have the following lemma.

Lemma 3 *The introduction regime is unstable; the economy in the introduction regime necessarily shifts to the invention regime.*

4 Invention Traps and Innovation Cycles

In this section, we will demonstrate our main result. An economy with too strong or too weak receptivity to novelty is caught in an underdevelopment trap in which new goods are constantly invented but any of them is introduced as old goods; there is no innovation. Only with moderate receptivity can the economy achieve perpetual innovation.

4.1 A Benchmark

Before proceeding, we, first, present a special case with a unit elasticity of substitution between goods. With $\sigma = 1$, the condition in Lemma 2 becomes:

$$\frac{\beta(\mu-1)L-1}{\beta(\mu-1)+1} < \frac{1}{\kappa}. \quad (29)$$

Independent of the consumer receptivity ε , this inequality always holds, due to the feasibility condition (see footnote 24). This case, therefore, provides us with a convenient benchmark from which we depart in identifying the role of the consumer's preference for new inventions, ε , in innovation and growth.

By Lemmata 2 and 3, the benchmark economy is necessarily caught in the trap; any path starting from any initial point, in either regime, eventually stays in the invention regime. As we have already seen, such an economy invents new goods every period, but any of them become simply obsolete, not transformed into old goods. The consumer's receptivity to novelty ε plays no role; this is because, in the present case, the preference parameter ε does not affect demands and profits, as $\sigma = 1$ (i.e., the expenditure share of the consumer for new goods, to old goods, is constant with the Cobb–Douglas preference).

Remark 1 *The consumer's receptivity to novelty ε has no role in equilibrium if the consumption goods are independent goods (i.e., $\sigma = 1$). In this benchmark case, independent of ε , the economy is fatally caught in the equilibrium trap, in which there is no innovation in the long run.*

Remark 1 implies that without a role of receptivity ε , our economy cannot achieve innovation and growth in the long run. In what follows, we will relax the knife-edge assumption $\sigma = 1$ to demonstrate the possibility of *receptivity-driven* innovation and derive a condition under which it actually occurs in equilibrium.

4.2 The Role of Receptivity in Innovation

In this section, we depart from the benchmark to characterize the essential role of receptivity ε in innovation, by assuming substitutability, that is, $\sigma > 1$. First, let us consider the case where $\Theta < \varepsilon^{\sigma-1}/\kappa$. In other words, the economy's inventive potential Θ is relatively low and, at the same time, the consumer's receptivity to novelty ε is relatively high. On the one hand, the invention regime is larger due to a high ε . On the other hand, the invention flow $N(t)$ within the regime tends to be low, due to a low Θ . As shown in Lemma 2, the economy behaves as if in the benchmark case, fatally caught in an equilibrium trap with no innovation.

Given that the invention potential Θ is an increasing function in ε , there will be a mixed role of ε , under the assumption of $\sigma > 1$. If the receptivity to novelty ε is high, on the one hand, the consumer will prefer new goods to old goods. With this effect, the invention of new goods becomes more profitable than does the introduction of new goods, as old ones, and, thus, the invention regime $(0, \varepsilon^{\sigma-1}/\kappa)$ will become large, through the market mechanism. This will make the economy more likely to get caught in what we call the invention trap. On the other hand, a higher ε results in a higher Θ . This means that the potential demand for new goods Θ is large. This increase in Θ is accompanied by an increase in the equilibrium number of new goods $N(t)$. Firms can meet more new goods that are available for introduction. With this effect of ε through the matching effect, the left-hand side of $\Theta < \varepsilon^{\sigma-1}/\kappa$ increases, and the economy is less likely to be trapped. These two opposite effects interact to create an ambiguous role for the receptivity to novelty ε . To see which effect dominates, we present the following lemma, recalling the lower bound of ε , $\varepsilon > \varepsilon_0 \equiv [1/(\beta(\mu - 1)L)]^{1/(\sigma-1)}$.

Lemma 4 *If*

$$L < 2\sqrt{\frac{1}{\kappa} \left(1 + \frac{1}{\beta(\mu - 1)}\right) \frac{1}{\beta(\mu - 1)}} \equiv L_0, \quad (30)$$

$\Theta < \varepsilon^{\sigma-1}/\kappa$ holds for any $\varepsilon > \varepsilon_0$. Otherwise, there exists $\varepsilon_+ \geq \varepsilon_- > \varepsilon_0$, such that $\Theta < \varepsilon^{\sigma-1}/\kappa$ holds if (and only if) $\varepsilon \notin [\varepsilon_-, \varepsilon_+]$.

Proof. Rewriting $\Theta < \varepsilon^{\sigma-1}/\kappa$, we obtain

$$F(\varepsilon^{\sigma-1}) \equiv \frac{1}{\kappa} \left(1 + \frac{1}{\beta(\mu-1)} \right) (\varepsilon^{\sigma-1})^2 - L\varepsilon^{\sigma-1} + \frac{1}{\beta(\mu-1)} > 0, \quad (31)$$

which is a second-order polynomial inequality in terms of $\varepsilon^{\sigma-1}$. Since the leading coefficient is positive, this inequality is always true if the discriminant is negative; that is to say:

$$D := L^2 - \frac{4/\kappa}{\beta(\mu-1)} \left(1 + \frac{1}{\beta(\mu-1)} \right) < 0,$$

which is equivalent to (30). For $D \geq 0$, let

$$\varepsilon_-^{\sigma-1} = \frac{L - \sqrt{D}}{(2/\kappa)(1 + 1/(\beta(\sigma-1)))}, \quad \varepsilon_+^{\mu-1} = \frac{L + \sqrt{D}}{(2/\kappa)(1 + 1/(\beta(\mu-1)))}. \quad (32)$$

For any $\varepsilon^{\sigma-1}$ between $\varepsilon_-^{\sigma-1}$ and $\varepsilon_+^{\sigma-1}$ or at one of them, the left-hand side of (31), that is, $F(\varepsilon^{\sigma-1})$, is nonpositive, and otherwise it is positive. Finally, to show $\varepsilon_- > \varepsilon_0$, let us suppose $\varepsilon_0^{\sigma-1} \geq \varepsilon_-^{\sigma-1}$; then, $\varepsilon_0^{\sigma-1} > \varepsilon_+^{\sigma-1}$ must hold, because $F(\varepsilon_0^{\sigma-1}) = (\beta(\mu-1)/\kappa) (1 + 1/(\beta(\mu-1))) (1/(\beta L(\mu-1)))^2$ is strictly positive.²⁵ Taking, for instance, $\varepsilon^{\sigma-1} = \varepsilon_1^{\sigma-1} \equiv 2/(\beta L(\mu-1)) > \varepsilon_0^{\sigma-1}$, $F(\varepsilon_1^{\sigma-1}) > 0$ must also hold, since $\varepsilon_1^{\sigma-1} > \varepsilon_0^{\sigma-1} > \varepsilon_+^{\sigma-1}$. However, by substituting $\varepsilon^{\sigma-1} = \varepsilon_1^{\sigma-1}$ into (31), we verify that $F(\varepsilon_1^{\sigma-1}) > 0$ can hold only for $D < 0$, which contradicts $D \geq 0$. ■

Lemma 4 implies that the economy will become fatally trapped in the invention regime if the country size, L , is too small; this clarifies an essential role of the so-called scale effect within the model. While the existence of the scale effect has been empirically rejected from a long-run perspective, by using 100 years of data (Jones 1995), it might play a role in world development in the *very* long run, such as in terms of millennia: As Boserup (1965) argues, population growth often triggers the adoption of new technology, since people are forced to adopt new technology when their population becomes too large to be supported by existing technology. The empirical finding of Kremer (1993) also suggests that total research output increases with population.²⁶ Consistent with these views, Lemma 4 shows that population size affects innovation and growth in the long run. The threshold level of L in (30), L_0 , comprises several parameters. Since, for instance, L_0 decreases with κ , the productivity of firms has a role in avoiding traps, which is natural and intuitive. In the remainder of this paper, to focus on receptivity ε , we restrict our analyses to the case with $L \geq L_0$.

Another important implication of Lemma 4 is that only an economy with moderate receptivity to novelty ε , such as $\varepsilon \in [\varepsilon_-, \varepsilon_+]$, can avoid falling into traps. In other words, if consumers' preferences for new goods are too strong or weak, the economy can be caught in an invention trap. That is, $\varepsilon \notin [\varepsilon_-, \varepsilon_+]$ is the trap condition. This nonlinear effect comes from the interaction between the two opposite roles of ε . When the consumer hardly appreciates new goods, and there is, therefore, a very low ε , the potential demand for new goods Θ is also too small for firms to find an enough amount of new goods, $\chi(t)N(t)$. When the consumer very much appreciates new goods, with a very high ε , the investment in invention is very profitable, making the threshold $\varepsilon^{\sigma-1}/\kappa$ much higher.

²⁵Potentially, because of $F(\varepsilon_0) > 0$, either $\min\{\varepsilon_-, \varepsilon_+\} > \varepsilon_0$ or $\max\{\varepsilon_-, \varepsilon_+\} < \varepsilon_0$ necessarily holds, given that the leading coefficient of $F(\varepsilon^{\sigma-1})$ is positive.

²⁶According to Kuznets (1960) and Simon (1977), a higher population means more potential investors.

With this high $\varepsilon^{\sigma-1}/\kappa$, the economy can scarcely emerge from such a large invention regime. These two forces interact with each other to create the nonlinear effect of ε .

Proposition 1 (Extreme Receptivity Causes Innovation to Fail Eventually)

When the infinitely lived consumer's receptivity to novelty ε is sufficiently low or high, such that $\varepsilon \notin [\varepsilon_-, \varepsilon_+]$, there is a globally stable equilibrium trap, n^ . The economy necessarily converges to the situation in which invention occurs, but there is no innovation in the long run.*

Proof. It is straightforward from Lemmata 1–4. ■

Proposition 1 implies that not only the “fear of novelty” (Beveridge 1959, Barber 1961), but also love of novelty may cause an economy to fall into a no-innovation trap. Together with Remark 1, this critical effect of consumer receptivity to novelty ε appears only when consumption goods are gross substitutes. Intuitively, given that new and old goods are substitutes ($\sigma > 1$), a consumer with a weak preference for new goods (low ε) and who suffers from a fear of novelty will have a small demand for new goods, which are the origins of old goods. This effect discourages the efficiency of matching for introduction, causing the economy to be more likely to be caught in the invention regime. Meanwhile, there is another relative effect of low ε , where inventing a new good becomes less profitable than does introducing new goods; such circumstances would shrink the invention regime itself (i.e., a lower threshold $\varepsilon^{\sigma-1}/\kappa$). This causes the economy to be less likely to be caught in the invention regime. As shown in Proposition 1, these two opposite effects—each emerging with the market mechanism and the matching effect—interact with each other to generate the nonlinear effect of the receptivity to novelty ε . On the one hand, if preferences for new goods ε are sufficiently weak, our result shows that the former absolute effect dominates—that is, the invention of new goods ($N(t)$) is too slow to exceed the threshold, $\varepsilon^{\sigma-1}/\kappa$. On the other hand, if a consumer has a strong preference for new goods (high ε), with a love of novelty, the latter relative effect dominates. The invention $N(t)$ is rapid due to the former effect, but the invention regime, $(0, \varepsilon^{\sigma-1}/\kappa)$, is large due to the latter effect. As in the case of a small ε , therefore, the economy tends to be trapped in the invention regime. Consequently, both too much fear and too much love of novelty can generate a stable underdevelopment trap in equilibrium.

What if the receptivity to novelty ε were moderate, such that $\Theta > \varepsilon^{\sigma-1}/\kappa$ holds? In this case, any equilibrium path achieves self-sustained innovation perpetually. By Lemma 2, an economy that falls in the invention regime in some period, say t , will go out of it to the introduction regime in the subsequent period, $t + 1$. By Lemma 3, any economy in the introduction regime necessarily moves to the invention regime. Any path starting from anywhere (in either regime) perpetually fluctuates, moving back and forth between the two regimes. We may interpret this equilibrium path as an innovation cycle, in the sense that innovation takes place only in the introduction regime.

We summarize this finding as a proposition.

Proposition 2 (Moderate Receptivity Supports Perpetual Innovation) *When the infinitely lived consumer's receptivity to novelty ε is moderate, such that $\varepsilon \in [\varepsilon_-, \varepsilon_+]$, the economy necessarily avoids traps and achieves perpetual innovation.*

Proof. It is straightforward from Lemmata 1–4. ■

As mentioned in the Introduction, our innovation cycle is new to the literature (Shleifer 1986), in the sense that, in our model, innovation covers the entire process in which new goods are invented and, then, introduced to take root in the economy (as old goods). Note that both invention and introduction are endogenous, time-consuming, and costly activities. Our result contributes to the literature on innovation cycles by showing the existence of a new innovation cycle over which invention and introduction endogenously alternate along an equilibrium path. This cycle is consistent with some historical facts argued in Mokyr (2000) and his related articles, indicating that invention and introduction typically take place at different times.

In Propositions 1 and 2, we demonstrate that an economy with too much receptivity or aversion to novelty becomes caught in an underdevelopment trap, where there is only invention, and no innovation takes place. Only an economy with moderate receptivity to novelty ε can achieve self-sustained innovation.

In order to see the effects of receptivity on economic growth, we verify that, in our model, innovation as the introduction of new goods as old goods is the only engine of long-run growth. To proceed, we follow the standard definition of an “economic growth rate”: $\gamma(t) \equiv (u(t+1) - u(t))/u(t)$. By using (2), (11), (14), and (17), we obtain $u(t) = \tilde{u}(t)A(t)^{\frac{1}{\sigma-1}}$, where $\tilde{u}(t) = (E(t)/w(t)) (1 + \varepsilon^{\sigma-1}N(t)/A(t))^{\frac{1}{\sigma-1}}$ includes the wage-measured expenditure, $E(t)/w(t)$, and the fraction of new goods, $N(t)/A(t)$. When $\Theta < \varepsilon^{\sigma-1}/\kappa$, the economy is caught in a trap. In a trapped economy, $N(t) = \Theta A(t)$, while both $E(t)/w(t)$ and $A(t)$ are constant over time. The growth rate is, thus, equal to $\gamma(t) = 0$. This implies that while generating inventions, any trapped economy cannot achieve self-sustained long-run growth. Using Proposition 2, therefore, we may conclude that having moderate receptivity to novelty ε is essential to self-sustained *growth* as well as innovation.

Now combine Propositions 1 and 2 in order to obtain the following theorem.

Theorem 1 *Individual receptivity to novelty has a non-monotonic relationship with innovation and growth in the long run.*

This theorem establishes the important result that *receptivity to novelty is not always good for innovation and growth; too strong or too weak receptivity hurts innovation and growth at the aggregate level*. This is clearly consistent with the recent empirical evidence that we mentioned in the Introduction. Therefore, we believe that our theory provides an economic explanation for the inverted-U relationship between individual propensities for novelty and macroeconomic performance found in recent empirical analyses. Putting it simply, the theory says, consumers’ receptivity to novelty encourages firms to invent new goods but discourages them from introducing, via the market mechanism. A larger number of goods are, then, newly invented in the market, whereby there is an added incentive for firms to introduce new goods (into old goods), via the matching efficiency effect. Receptivity, therefore, has an ambiguous effect on innovation and growth. The explanation here is fully endogenous, based on incentives and markets.

Theorem 1 also suggests a role of governments in innovation to “fix” overly high or overly low receptivity among individuals, and adjust it to a moderate level. In some countries, policies unintentionally affect receptivity to novelty. For example, in the U.S., the authority of the Department of Health and Human Services to fund human embryonic stem-cell research had been limited by U.S. Presidential actions from 2001 to 2009.

These limitations were removed by U.S. President Barack Obama in March 2009.²⁷ The Internet provides another example. Until 1995, the U.S. government restricted the use of the Internet to non-commercial purposes. Although the market grew rapidly after deregulation, many market participants had been unwilling to accept the forthcoming policy change when the removal of the restriction was on the table. Our result suggests that the government can play a role in promoting innovation by avoiding excessively high or low receptivity among individuals.

5 An Extension: Balanced Growth and Path Dependence

In this section, we explore an extension of our baseline model. Our model features only traps and cycles in dynamic equilibrium. Therefore, we allow for the model to have balanced growth.

For that purpose, we add minimal elements to the process of innovation. Following Anderlini et al. (2013), we introduce an exogenous growth factor, $\eta(t) \geq 0$, into the baseline model;²⁸ the number of endogenous inventions, $R^N(t)$, together with the number of exogenously produced inventions, $\eta(t)$, determine the dynamics of new goods by $N(t+1) = R^N(t) + \eta(t)$. For the sake of simplicity, we further assume $\eta(t) = \eta N(t)$, with $\eta \in [0, 1)$.²⁹ When $W^n(t) = 0$, thus, the new good $N(t)$ evolves in the invention regime due to

$$N(t+1) = \Theta A(t) + \eta N(t), \quad (33)$$

which corresponds to (23). When $W^a(t) = 0$, the free entry condition similar to (26) is now

$$\rho(t+1) = \frac{\kappa\beta}{\mu/(\mu-1)} \frac{E(t)}{w(t)} - \frac{A(t)}{N(t)} - \eta\varepsilon^{\sigma-1}, \quad (34)$$

which uses $N(t+1) = \eta N(t)$ since $R^N(t) = 0$. From (25) and (34), the old good $A(t)$ evolves due to

$$\rho(t+1) = \frac{1}{1 + \beta(\mu-1)} \left(\beta(\mu-1)\kappa L - \frac{A(t)}{N(t)} - \eta\varepsilon^{\sigma-1} \right).^{30} \quad (35)$$

Combining (33) and (35), we can derive the equilibrium dynamical system as:

$$n(t+1) = \begin{cases} \eta n(t) + \Theta \equiv \varphi^N(n(t)) & \text{for } n(t) < \varepsilon^{\sigma-1}/\kappa \\ \frac{\eta(1+\beta(\mu-1))n(t)}{\beta(\mu-1)+(\beta(\mu-1)\kappa L - \eta\varepsilon^{\sigma-1})n(t)} \equiv \varphi^A(n(t)) & \text{for } n(t) > \varepsilon^{\sigma-1}/\kappa \end{cases}, \quad (36)$$

²⁷For details, see Executive Order 13505 of March 9, 2009, titled “Removing Barriers to Responsible Scientific Research Involving Human Stem Cells.”

²⁸Exogenous innovation is often assumed in research for a deeper understanding of, not the cause of innovation but, the role of innovation in various phenomena; see, for instance, Lucas and Moll (2014) and Benhabib et al. (2017). Given that our goal in the present paper is to investigate the cause of innovation, our extended model still has endogenous innovation, $R^N(t)$, more in accordance with Anderlini et al. (2013), who consider both endogenous and exogenous components in the innovation process.

²⁹If $\eta > 1$, the new good, $N(t)$, autonomously expands without the help of endogenous invention. Given the focus of our paper, we should restrict the exogenous growth factor to be lower than 1; $\eta < 1$.

³⁰To ensure feasibility, such that $\rho(t+1) \in (0, 1)$ for any $n(t)$ in the introduction regime, it would suffice to assume $\beta(\mu-1)\kappa L - ((\beta(\mu-1) + \kappa/\varepsilon^{\sigma-1} + 1) < \eta\varepsilon^{\sigma-1} < \beta(\mu-1)\kappa L$.

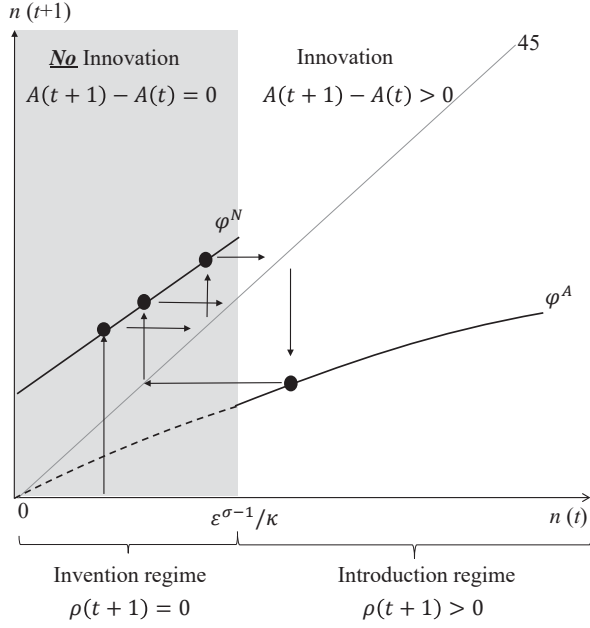


Figure 4a: Innovation Cycles with $\varepsilon \in (\varepsilon_-, \varepsilon_+)$

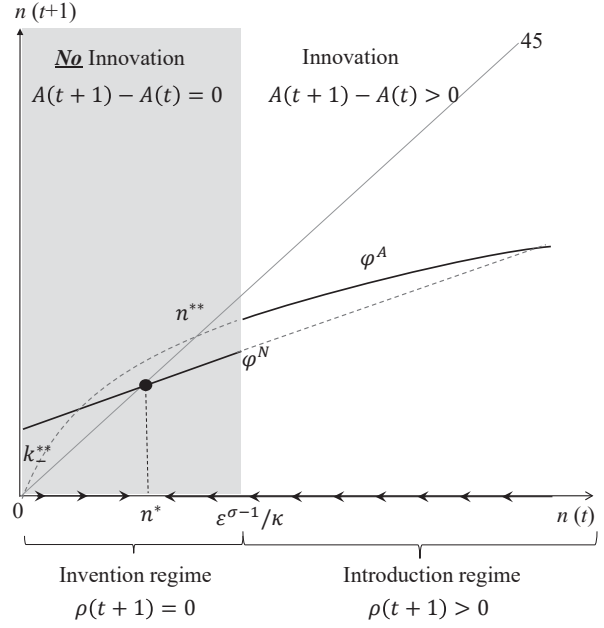


Figure 4b: Global Trap with $\varepsilon \notin (\varepsilon_-, \varepsilon_+)$

which uses (4).³¹ Function φ^N is linear and φ^A is concave, and both are increasing in $n(t)$, each of which has a unique fixed point for $n(t) > 0$, labelled n^* and n^{**} , respectively.

Proposition 1 still holds, but locally; the conditions also change slightly. (A proof requires a tedious sequence of similar calculations, which is omitted here.)³² Suppose

$$L > \sqrt{\frac{1-\eta}{\kappa} \left(1 + \frac{1}{\beta(\mu-1)\kappa}\right) \frac{1}{\beta(\mu-1)}} \equiv L'_0.$$

Then we have the following proposition.

Proposition 3 *In the extended model with the coexistence of endogenous and exogenous inventions, if the infinitely lived consumer's receptivity to novelty ε is sufficiently low or high, such that $\varepsilon \notin [\varepsilon'_-, \varepsilon'_+]$,³³ there is a locally stable equilibrium trap, n^* . Once the economy falls into the invention regime, it is trapped and converging to the situation, n^* , in which invention occurs, but there is no innovation in the long run.*

Concerning the introduction regime, there are two possibilities. First, if n^{**} exists outside the introduction regime, the equilibrium behavior of the economy is quite similar to that in Proposition 2. That is, the economy may achieve innovation perpetually but cyclically, as shown in Figure 4a. Otherwise, it may be fatally caught in the global trap, as shown in Figure 4b. Second, if n^{**} is included in the introduction regime, it may work as a globally stable steady state, as shown in Figure 4c. On that point, the number of new goods, $N(t)$, and that of old goods, $A(t)$, grow at the same rate. Therefore, in this case,

³¹We also use $A(t+1) = A(t)$ for $n(t) < \varepsilon^{\sigma-1}/\kappa$ and $N(t+1) = \eta N(t)$ for $n(t) > \varepsilon^{\sigma-1}/\kappa$. In order to ensure $n(t+1) > 0$ for any $n(t) > \varepsilon^{\sigma-1}/\kappa$, we impose an upper bound of ε . $\varepsilon < [(\kappa/\eta)\beta(\mu-1)L]^{1/(\sigma-1)}$.

³²A formal proof is available upon request from the authors.

³³Note that ε'_- and ε'_+ are solutions to the quadratic equation in ε , given by $n^* = \varepsilon^{\sigma-1}/\kappa$, with $n^* = \Theta/(1-\eta)$. They are quite similar to ε_- and ε_+ in Lemma 4.

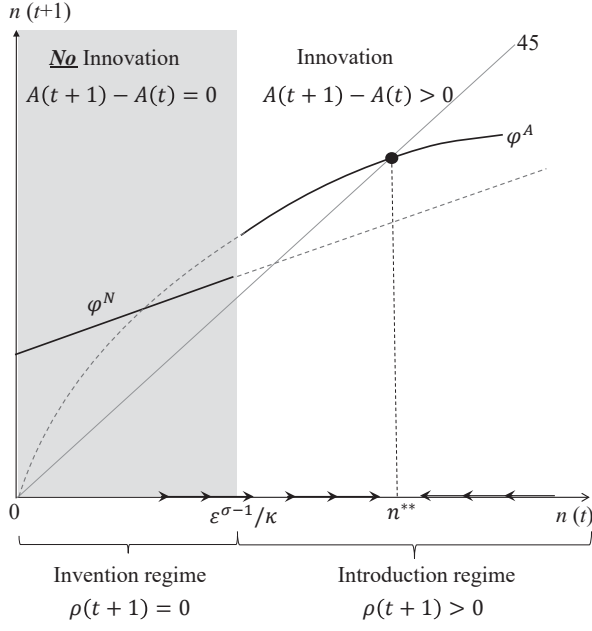


Figure 4c: Balanced Growth with $\varepsilon \in (\varepsilon_-, \varepsilon_+)$

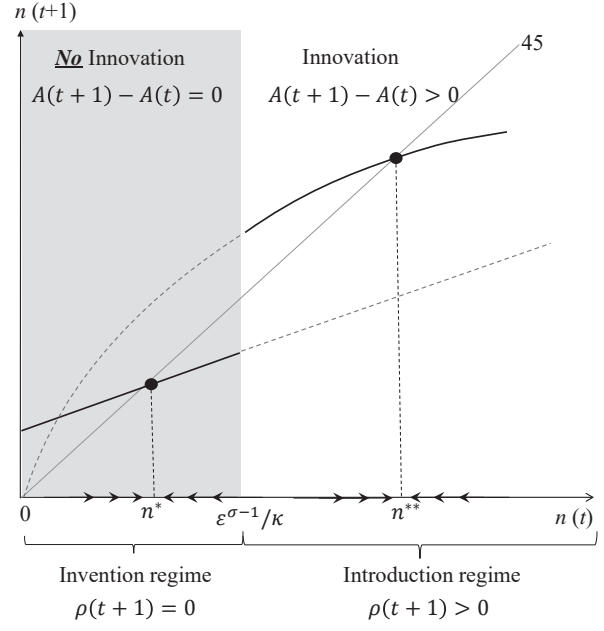


Figure 5: Path Dependency with $\varepsilon \notin (\varepsilon_-, \varepsilon_+)$

any path starting from any initial state converges to point n^{**} that gives the economy balanced growth, as in the standard growth model. It is worth mentioning that in either case, the economy achieves perpetual innovation and growth if $\varepsilon \in [\varepsilon'_-, \varepsilon'_+]$, corresponding to Figures 4a and 4c. Therefore, Proposition 2 will be revised in this extended model, without any essential change.

Proposition 4 *In the extended model with the coexistence of endogenous and exogenous inventions, if the infinitely lived consumer's receptivity to novelty ε is moderate, such that $\varepsilon \in [\varepsilon'_-, \varepsilon'_+]$, the economy necessarily avoids traps and achieves perpetual innovation. The growth path is either cyclical or balanced.³⁴*

Figure 5 depicts another interesting case that emerges from the present extension. There are two locally stable steady states; whether the economy converges to a balanced growth path or invention trap depends on the initial condition. There is so-called path dependence, implying that the economy may suffer from a lock-in by virtue of historical events (e.g., Arthur 1989).

6 Concluding Remarks

In the present study, we explored the relationship between individual receptivity to novelty and innovation at the aggregate level. We first used data from the World Values Survey and the World Intellectual Property Organization to show that the relationship may be more complex than is naturally considered. We showed that, unconditionally, innovation tends to be higher at the medium level of receptivity but lower at the two

³⁴It is easy (but tedious) to derive a condition under which the growth path is balanced. A formal proof is available upon request from the authors.

ends of the receptivity distribution. We offered a new theory that provides a useful basis for interpreting such a complex relationship between receptivity and innovation. In doing this, we developed a new R&D-based growth model, in which (i) innovation consists of two separate creative activities that both require investments, i.e., the invention of new goods and their introduction to old goods, and (ii) the infinitely-lived representative consumer has different preferences to new and old goods.

The endogenous growth literature has, thus far, emphasized the importance of endogenous innovation as an engine of long-run growth (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992). The existing models were basically designed to identify the role of innovation through its ultimate contribution to the long-run growth rate, but neither explicitly through its internal process of interacting with different stages in the growth process nor its relation to the receptivity to novelty as a cultural preference. In the model that we developed, invention and introduction are treated as discrete (and costly) activities that interact with each other to achieve innovation and govern the evolution of an economy. In our model, we clearly distinguished the invention of a new good from its introduction, by considering a new preference parameter. Using the model, we then examined the role of receptivity to novelty in creating self-sustained innovation and endogenous growth in several forms such as innovation cycles, balanced growth, and history dependence. The model was designed to be simple and tractable, and, yet, capable of drawing new insights into the role of innovation in economic growth and providing a theory supported by the new fact that we documented in the Introduction.

Needless to say, the present study offers only a glance at how receptivity to novelty affects innovation-driven growth, when we earnestly delve into the details of the complex process of innovation. Our proposed model does not contain all of the aspects of receptivity/aversion to novelty or innovation. It is, for example, considered exogenous, but it may change over time, in line with consumer behavior. Although the formulation of matching takes a very simple form, we could work with a more general setting, such as a Cobb-Douglas matching function. These restrictions help make analysis sufficiently tractable, but they also make the equilibrium unrealistic. Most importantly, in the present model, there is no equilibrium where invention and introduction coexist; in reality, however, the two components of innovation often take place concurrently. For future research, one can rectify this problem by assuming strictly concave, rather than linear, technologies. Otherwise, allowing for consumers' learning activities with regard to novel products would also work sufficiently. Nevertheless, given its simplicity, we believe that our model has an advantage over such extended models: the equilibrium dynamic system is quite simple and, therefore, all analyses can be undertaken analytically to demonstrate two interesting dynamic phenomena, that is, equilibrium traps and innovation cycles.

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Appendix A: Regression Analysis

In Figure 1 in the Introduction, we observed an unconditional, hump-shaped relationship between receptivity and innovation. To statistically verify it, this appendix presents a more formal regression analysis.

Data sources We use data the World Intellectual Property Organization (WIPO) to obtain patent applications for various countries. To measure receptivity, we use data from the World Values Survey (WVS). In particular, we use the survey question E046 which asks respondents to give a score to the statement “Ideas stood test of time better vs New ideas better.” The score ranges from 1 (“Ideas that stood test of time are generally best”) to 10 (“New ideas are generally better than old ones”).

We also use WVS to construct two measures of religiosity. Specifically, we use the survey questions F034 and F050. F034 asks whether the respondent is a religious person (the survey question is: “Independently of whether you go to church or not, would you say you are ...” with possible answers 1 (“A religious person”), 2 (“Not a religious person”), and 3 (“A convinced atheist”).) F050 asks whether the respondent believes in god (the survey question is: “Which, if any, of the following do you believe in? ... God” with possible answers 0 (“No”) and 1 (“Yes”).)

As for other control variables, we obtain data for GDP and population from the World Bank and data for the net inflow of foreign direct investment (FDI) as a percentage of GDP from the World Development Index (WDI); the index of patent rights comes from Park (2008); data for years of tertiary schooling come from Barro and Lee (2013); we also use WVS data to construct the two religiosity measures (share of religious people and share of people believing in God).

Variable definitions Using the patent applications data from WIPO and population data from the World Bank, we compute the innovation variable as $\log(\text{Average patent applications over 2010-2014}_c / \text{Average population in million over 2010-2014}_c)$.

To compute the receptivity measure, $Receptivity_c$, we start with the full individual-level sample from WVS (1981-2014). We drop observations with missing values in E046; the resulting sample covers the period 1989-2002. We then collapse the sample into country-level means to obtain $Receptivity_c$.

Other control variables in the regression analysis are also country-level means. More specifically, the index of patent rights is the average over 1960-1990; population, GDP per capita, and FDI (as % of GDP) are the averages over 1960-1990; years of tertiary schooling are the average over 1960-1990; the religiosity measures (share of religious people and share of people believing in God) are the averages over 1981-2002.

The main reason of creating some “time lags” between the key outcome variable, the key independent variable, and other control variables is to address some of the endogeneity and reverse causality concerns.³⁵

Sample characteristics Based on the above variable definitions, we obtain a sample with 52 observations (with non-missing $Innovation_c$ and $Receptivity_c$), 29 (with non-missing values in all other control variables). Note that there are two outliers in $Receptivity_c$ (Bangladesh and Colombia): Their values are 8.38 and 8.21 respectively

³⁵Note that while the raw data have a panel structure, we may not be able to come up with a panel directly to estimate a panel regression because many variables are not contemporaneous.

whereas the maximum value of the remaining countries is about 6.46 (see Table 1 for the summary statistics of the sample). In the above empirical analysis, we drop these two outliers.

Regression results We estimate the following quadratic regression to identify whether, after controlling for several country-level characteristics, there is still a non-linear relationship between receptivity and innovation:

$$Innovation_c = \alpha + \beta_1 Receptivity_c + \beta_2 (Receptivity_c)^2 + \delta X_c + \varepsilon_c. \quad (37)$$

In this regression, c indexes a country, $Innovation_c$ and $Receptivity_c$ are the innovation and receptivity measures. X_c is a vector of other country-level control variables, including log GDP per capita, log Population, intellectual property protection, years of tertiary schooling, net inflow of foreign direct investment as a percentage of GDP, religiosity; these control variables are also used in Benabou et al. (2016). Finally, ε_c is the error term.

Table 2 shows the regression results of (37). In Column (1), we regress $Innovation_c$ on $Receptivity_c$ and its square term only. The coefficient of $Receptivity$ is positive and that of the square term is negative; both coefficients are statistically significant, suggesting that, unconditionally, there is a non-linear (inverted-U) relationship between the two variables. In Column (2), we control for the country-level characteristics except the religiosity variables in the regression. Finally, Benabou et al. (2016) find that innovation is negatively related people's religiosity; in Columns (3) and (4), we further control for the share of religious people and the share of people believing in God. In these other regressions, we still obtain similar results. Besides, the signs of the coefficients of these control variables are in general consistent with those reported in Benabou et al. (2016). Overall, this analysis shows that, after controlling for some country-level characteristics, we find an inverted U-shaped relationship between $Innovation_c$ and $Receptivity_c$. The regression results imply that $Innovation_c$ reaches the maximum when $Receptivity_c$ is roughly around 4.2 to 4.6. Certainly, the results reported in Table 2 only imply associations rather than causality. Nevertheless, these results provide the motivation for us to study the model developed in the present paper.

Table 1: Summary statistics

Variable	N	Mean	S.D.	Min.	1st quart.	Median	3rd quart.	Max.
$Innovation_c$	50	3.667	2.030	-1.553	2.698	3.696	5.038	7.996
$Receptivity_c$	50	5.109	0.605	3.767	4.607	5.209	5.510	6.455
GDP per capita (log)	29	8.842	1.410	5.677	8.255	8.708	10.091	10.962
Population (log)	29	3.620	1.533	1.223	2.318	3.568	4.392	7.208
Index of patent rights	29	2.112	0.853	0.590	1.380	2.120	2.750	4.140
Years of tertiary schooling	29	17.572	11.236	0.586	9.700	16.800	21.871	52.914
FDI (as % of GDP)	29	0.607	0.609	-0.058	0.179	0.471	0.930	2.341
% religious people	29	0.659	0.216	0.098	0.528	0.746	0.821	0.939
% people believing in God	27	0.855	0.152	0.514	0.793	0.927	0.975	0.995

Table 2: Receptivity and innovation: Regression analysis

	(1)	(2)	(3)	(4)
<i>Receptivity_c</i>	12.773** (6.169)	11.661* (6.744)	14.341*** (5.276)	11.748** (5.344)
<i>(Receptivity_c)²</i>	-1.400** (0.614)	-1.389** (0.643)	-1.554*** (0.522)	-1.310** (0.522)
GDP per capita (log)		0.547* (0.286)	0.526** (0.227)	0.509** (0.249)
Population (log)		0.098 (0.154)	0.242** (0.121)	0.219* (0.125)
Index of patent rights		0.889*** (0.320)	0.596** (0.251)	0.522** (0.213)
Years of tertiary schooling		-0.014 (0.028)	0.001 (0.018)	0.005 (0.018)
FDI (as % of GDP)		-0.018 (0.280)	-0.085 (0.246)	0.195 (0.269)
% religious people			-4.049*** (0.893)	
% people believing in God				-5.716*** (1.723)
Constant	-24.545 (15.353)	-25.298 (17.097)	-32.151*** (12.327)	-23.054* (12.310)
Observations	50	29	29	27
<i>R</i> ²	0.279	0.769	0.853	0.872

Note: The dependent variable is Patent applications per million capita (log). Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.